NEW HAMPSHIRE FLOOD PLAIN MANAGEMENT SERVICES

SUNAPEE LAKE DAM AND TOWN DAM DAM-BREACH FLOOD ANALYSIS TOWNS OF SUNAPEE AND NEWPORT, NEW HAMPSHIRE

APRIL 2000

US Army Corps
of Engineers

New England District

SUNAPEE LAKE DAM AND TOWN DAM
DAM-BREACH
FLOOD ANALYSIS

Town of Sunapee, New Hampshire
and
Town of Newport, New Hampshire

PREPARED FOR:

State of New Hampshire
Department of Environmental Services
Water Division

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Department of the Army
New England District, Corps of Engineers
Concord, Massachusetts

April 2000

Sunapee Lake Dam and Town Dam
Dam-Breach Flood Analysis

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Dam-Breach Flood Analysis

1. PURPOSE

This report presents the findings of a dam-breach flood analysis performed for the near simultaneous failure of the two dams at the outlet of Lake Sunapee. The primary regulating structure is the gate structure at the Lake's outlet in Sunapee Harbor. This dam is commonly known as the Sunapee Lake Dam. A second dam, known as the Town Dam, is located approximately 750 feet downstream of the gate structure. See Plate 1, for photographs of dams. Due to their close proximity and configurations, failure of only one of these dams would not create a threat to public safety. This study analyzed the failure of both dams at or about the same time, which would result in an uncontrolled release of approximately 20,000 acre-feet of water. The Sunapee Lake Dam is owned, operated and maintained by the New Hampshire Department of Environmental Services, Water Division. The Town Dam is owned, operated and maintained by the Town of Sunapee, New Hampshire.

Included in the report is a description of pertinent features of the dams, procedures used for the analysis, assumed dam-breach conditions, and the resulting effect on downstream flooded areas, particularly the Town of Sunapee. This study was not performed because of any known likelihood of a dam-breach at these dam. The purpose is to provide information for emergency planning use.

The dam-breach flood analysis was conducted at the request of the State of New Hampshire, under the authority of the Corps of Engineers Section 206 Flood Plain Management Services (FPMS) program. This report presents the findings of a dam-breach analysis performed assuming a sunny-day and storm-day failure of the two dams at the outlet of the Sunapee Lake.

2. MODEL DESCRIPTION

A dam-breach analysis for the dams was conducted using Boss Corporation's 1992 release of the National Weather Service Dam-Breach Flood Forecasting Computer Model developed by D.L. Fread. Input for the model consists of storage characteristics of the reservoir, selected geometry and duration of breach development, selected geometry of the Sugar River valley and hydraulic roughness coefficients for the downstream channel. Detailed descriptions of this data are discussed later in this report. Based on input data, the model computes the breach outflow hydrograph and routes it downstream. The analysis provides output on the attenuation of the flood hydrograph, and timing of the flood wave as it progresses downstream. These results are also discussed in detail.

3. DESCRIPTION

a. General. The Sunapee Lake Dam and the Town Dam are located in the central western part of New Hampshire in the town of Sunapee. The dams are built on the headwaters

of Sugar River. Sugar River flows westerly from Sunapee Lake to the Connecticut River in the City of Claremont, New Hampshire that is 17 miles west of Sunapee.

Sunapee Lake is a natural lake with the water surface in the lake being controlled by the Sunapee Lake Dam that is located about 750 feet upstream from the Town Dam. It has a drainage area of 46.7 square miles. Town Dam discharges into the Sugar River. The topography of the drainage area is rolling terrain and is heavily wooded.

The study extended from the Sunapee Lake Dam at Sunapee Lake downstream along the Sugar River through the Towns of Sunapee and Newport and terminated at a dam located at mile marker (MM) 16.17 approximately 4,000 feet upstream of the confluence of the South Branch of the Sugar River. The study reach included approximately six miles of the Sugar River. The study analyzed a dam failure at the Sunapee Lake Dam and subsequent failure at the downstream Town Dam. The drainage area contributing to the study reach increases from 46.7 square miles at the Sunapee Lake Dam to 52.9 square miles at the Sunapee – Newport Town Line and 76.0 square miles upstream of the confluence with the South Branch of the Sugar River. The study area reach is shown on Plate 2.

b. Sunapee Lake Dam and Town Dam. The Sunapee Lake Dam is located 750 feet east of the Town Dam on the Sugar River located in the Town of Sunapee, New Hampshire. The location of dams is shown on Plate 1. The surrounding land is heavily wooded with rolling terrain. The total drainage area of Sunapee Lake Dam is 46.7 square miles.

The Town Dam consists of stone masonry capped with concrete and a concrete slab over the upstream face. The overall length of the dam is 139 feet with a dam height of +/- 15 feet and the top of dam elevation of 1094.5 NGVD. The dam has four separate discharge facilities. The discharge facilities are described below:

- 5- foot diameter penstock connected to a hydraulic turbine.
- 5 ft x 5 ft waste sluice gate in the north abutment.
- 12-inch pipe that conveys water from Sunapee Lake to a pumping station for the Town of Sunapee's water supply.
- A 30-ft spillway with a crest elevation of 1090.5 NGVD.

TABLE 1

Pertinent Data
Town Dam

a. Drainage Area. The drainage area at the Town Dam is controlled by the upstream Sunapee Lake Dam. The drainage area at the Sunapee Lake Dam is 46.7 square miles consisting of rolling to steeply sloping terrain.

b. Elevations (feet NGVD)

(1) Top of dam – 1094.5 at the north abutment and 1095.0 at the south abutment
(2) Spillway crest – 1090.5
(3) Stream bed at centerline of dam – 1075.5 (estimated)

c. Reservoir Surface Area (acres)

(1) Spillway crest – 4,085 acres
(2) Top of dam – 4,500 acres

d. Dam

(1) Type – Dry rubble masonry
(2) Length - +/- 139 feet
(3) Height - +/- 15 feet above streambed
(4) Top width – varies, minimum 5.75 ft, maximum 14.5 ft
(5) Side Slopes
- upstream approximately 1 vertical to 1 horizontal
- downstream - vertical

(6) Impervious core – not applicable
(7) Cutoff – upstream face of dam concrete masonry with possibility of sheet piling.
(8) Grout curtain – none

e. Spillway

(1) Type – Ungated concrete weir
(2) Length of weir – 30 feet
(3) Crest elevation – 1090.5
(4) Gates – None
(5) U/S channel – Forebay pond (Sugar River)

f. Regulating Outlet

(1) Invert Elevation– 1083 (estimated)NGVD
(2) Size – 60-inch diameter
(3) Description – Steel penstock
(4) Control Mechanism – One gate valve, manually operated.
(5) Other
a. Invert Elevation– 1083 (estimated) NGVD
b. Size – 5 ft x 5 ft
c. Description – Concrete waste gate opening
d. Control mechanism – One gate, manually operated

TABLE 2

Pertinent Data

Sunapee Lake Dam

a. Drainage Area. The drainage area at the Sunapee Lake Dam is 46.7 square miles consisting of rolling to steeply sloping terrain.

b. Elevations (feet NGVD)

(1) Top of abutments – +/- 1100.8
(2) Top of Catwalk - +/- 1098.7
(3) Invert of gate seats – +/-1084.7

c. Reservoir Surface Area (acres)

(1) 4,085 acres at 1090.5 ft NGVD
(2) 4,500 acres at 1094.5 ft NGVD

d. Dam

(1) Type – Gate structure
The structure consists of three 5 ft wide X 10 ft high manually controlled sluice gates.
a. Gate seat elevation – +/-1084.7 ft NGVD
b. Top of gate in closed position – +/-1094.7 ft NGVD

e. Spillway – Not Applicable

c. Downstream Valley. Immediately downstream of Town Dam, for approximately 1,000 feet the channel slope is very steep averaging 300 feet per mile. However the majority of the Sugar River in the study area averages 33 feet per mile. There are several small flow structures and road crossings across the Sugar River between Town Dam and the dam in the

Town of Newport at MM 16.17, the downstream limits of the study. This study included four dams. The Sunapee Lake Dam (MM 10.00), the Town Dam (MM 10.12), Dam at Wendell Marsh (MM 11.90) and the dam at the downstream study limit MM 16.17. The dam at MM 16.17 is called the Sugar River I Hydro Dam (Dam No. 178.02).

All the cross sectional information describing the downstream Sugar River valley from MM 10.34 to MM 16.44 were obtained from the Flood Insurance Studies for the Towns of Sunapee and Newport. The cross sectional information describing the study reach from the Sunapee Lake Dam MM 10.00 to MM 10.34 was based on the information from the Phase I Inspection Report for the Sunapee Lake Town Dam and data obtained from the State of New Hampshire's Department of Environmental Services.

4. METHOD OF ANALYSIS

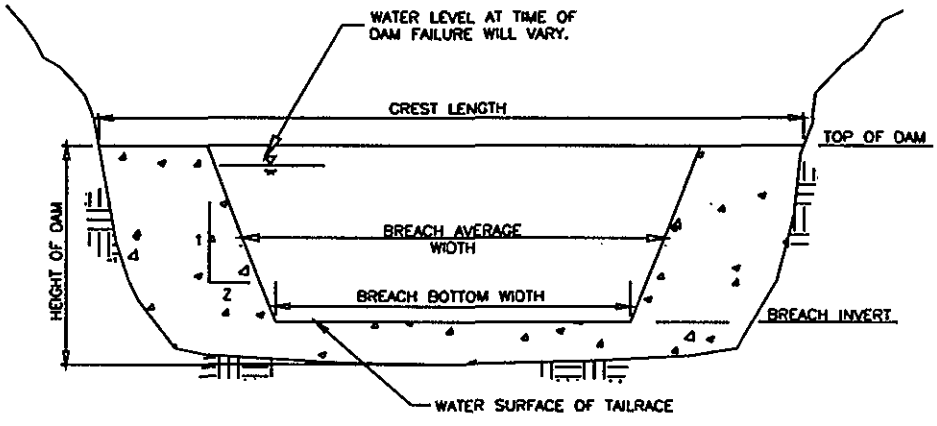
a. General. This section discusses the methods and assumptions used in the dam-breach analysis. The magnitude of a flood resulting from a hypothetical dam-breach depends not only on the size of the dam but also on the conditions of failure including the initial water level in the reservoir, size of the breach, rate of breach formation, as well as hydraulic features and initial flows in the downstream river channel. Two types of hypothetical dam failures were evaluated in this study, a sunny-day failure and a storm-day failure.

A **sunny-day** failure refers to a failure under normal water level usually associated with fair weather or non-flood conditions. It often results from piping, which is the progressive internal erosion of a soil mass such as an embankment, foundation or abutment of a dam from uncontrolled seepage carrying soil particles to an unprotected exit that over time creates an erosion cavity or pipe. Once this happens, a rapid failure of the dam can occur which releases the contents of the reservoir and forms the breach discharge. Piping is the most common cause of sunny-day failures of earth dams and other dams that are constructed on earth foundations or abutments. A sunny-day failure can also result from other causes, such as a sudden failure of a conduit under pressure or a structural component of the dam.

A **storm-day** failure is associated with major storm events and floods. During periods of significant rainfall and resulting runoff, the reservoir will rise to high levels. If the storm is severe enough, and the inflow exceeds the hydraulic capacity of the spillway and reservoir storage capacity, overtopping of the embankment can occur. As flood waters flow over the dam, the erosion of the earth embankment or abutments can occur resulting in a failure of the dam and the formation of the breach discharge as the contents of the reservoir are released. Other dam failure modes such as piping, sudden structural failure or progressive failure of stone or masonry elements can be a result of high reservoir levels associated with the storm-day type failures.

b. Assumed Dam Failure Scenario. For this project the hypothetical failure of two dams was evaluated. For this study it was assumed that the Sunapee Lake Dam (MM 10.00) would fail and the resulting dam breach flood wave would be routed to the downstream Town Dam (MM 10.12). Subsequently, the Town Dam would then fail as the routed dam breach flood wave from the Sunapee Lake Dam reaches its maximum stage at the Town Dam. See Table 3.

c. Assumed Breach Parameters. The discharge hydrograph of a breach is a function of the inflow hydrograph and breach parameters (time of breach formation, size, and shape of breach) of a hypothetical dam failure. The breach parameters are based on the FERC guidelines. The following sketch illustrates the various dam breach parameters for a typical earthen or concrete-gravity dam. Total outflow is a combination of flows through the breach and spillway. As the breach develops, so does the breach discharge. See Table 3.



Definition Sketch of Breach Parameters

d. Assumed Pre-breach Flows. Assumed pre-breach flows on the Sugar River for the dam failure simulation were developed for the downstream watershed. These are the assumed flows for the antecedent conditions that would be expected to occur with or without a dam failure.

- For the **sunny-day** failure scenario it was assumed the antecedent conditions at the dams and downstream along the Sugar River were approximately equal to the annual mean flow for the drainage area at the dam or 1.5 cfs per square mile of drainage area.
- For the **storm-day** failure it was assumed that the antecedent conditions at the dams and downstream along the Sugar River were equal to the 100-Year peak discharge of 870 cfs at the dam as documented in the Flood Insurance Study for the Town of Sunapee.
- It was assumed for the Sunny-day and Storm-day failure scenarios that there were no downstream lateral inflows from the downstream-uncontrolled drainage areas. See

Table 3. Downstream lateral inflows were not included with the sunny-day failure because the incremental increase in the drainage area from 46.7 square miles in the upstream study reach to 76.0 square miles in the downstream reach would not have a significant affect on the calculated dambreak flood elevations due to the Sugar River steep valley slope that averages approximately 33 feet per mile. Downstream lateral inflows were not included with the storm-day failure because it was assumed that antecedent peak flows from the downstream uncontrolled drainage areas would occur much earlier than the peak outflow from Sunapee Lake Dam due to the large surcharge storage in the lake. Sunapee Lake has approximately 11,000 acre-feet of surcharge storage from the normal summer lake elevation of 1093.15 to the estimated historical flood of record elevation of 1095.85. This surcharge storage is equivalent to 4.4-inches of runoff from Sunapee Lake's drainage area of 46.7 square miles and would result in considerable desynchronization of lake outflows and downstream flood peaks.

Table 3
Assumed Dam Breach Parameters for the Sunny-day and Storm-day failures at the Dams

Sunny-day Failure Conditions	
Sunapee Lake Dam	
Initial pool level at start of computations	El. 1093.15 NGVD
Pool level at dam failure	El. 1093.15 NGVD
Breach invert elevation	El. 1084.72 NGVD
Breach bottom width	21 feet with side slopes 0.0H : 1.0V
Time to complete formation of breach	0.20 Hours
Downstream reach roughness coefficients	0.04 to 0.08
Assumed pre-breach flows	70 cfs
Assumed downstream lateral inflows	None
Town Dam	
Initial pool level at start of computations	El. 1091.04 NGVD
Pool level at dam failure	El. 1092.80 NGVD
Breach invert elevation	El. 1075.00 NGVD
Breach bottom width	40 feet with side slopes 0.0H : 1.0V
Time to complete formation of breach	0.20 hours
Downstream reach roughness coefficients	0.04 to 0.08
Assumed pre-breach flows	70 cfs
Assumed downstream lateral inflows	None

TABLE 3 (CONT.)

Storm-day Failure Conditions	
Sunapee Lake Dam	
Initial pool level at start of computations	El. 1095.85 NGVD (1936 Historical Flood Level)
Pool level at dam failure	El. 1095.85 NGVD
Breach invert elevation	El. 1084.72 NGVD
Breach bottom width	21 feet with side slopes 0.0H : 1.0V
Time to complete formation of breach	0.20 Hours
Downstream reach roughness coefficients	0.04 to 0.08
Assumed pre-breach flows	870 cfs
Assumed downstream lateral inflows	None
Town Dam	
Initial pool level at start of computations	El. 1094.60 NGVD
Pool level at dam failure	El. 1095.30 NGVD
Breach invert elevation	El. 1075.00 NGVD
Breach bottom width	40 feet with side slopes 0.0H : 1.0V
Time to complete formation of breach	0.20 hours
Downstream reach roughness coefficients	0.04 to 0.08
Assumed pre-breach flows	870 cfs
Assumed downstream lateral inflows	None

e. Downstream Channel Routing. A downstream channel routing analysis allows the breach discharge hydrograph to be characterized at points of interest below the dam. The downstream channel stationing is in river miles below Sunapee Lake Dam, with river mile 10.0 at the dam. A breach hydrograph is attenuated and stored through the downstream channel and flood plain. The degree to which this breach discharge is attenuated is a function of the downstream valley storage capacity and valley roughness characteristics.

The dynamic wave method of channel routing is used in the NWS DAMBRK computer program to route the flood wave downstream. This is a hydraulic routing method that solves the complete unsteady flow equations through a given reach. Results of this method indicate attenuation of the flood wave, resulting flood stages, and the time it takes the wave to reach a section of the river.

Downstream valley data were determined by obtaining selected cross sections from WSP2 and HEC-2 input files from the Town of Sunapee and Newport, NH Flood Insurance Studies. Manning's "n" values were assigned to the channel and overbanks on the basis of the HEC-2 analysis and field observations. Discharge and stage hydrographs were selected at six downstream stations, river miles MM 10.00, MM 10.12, MM 10.93, MM 11.90, MM 12.75, and MM 16.17. and shown on Plates 15 and 17 for the sunny-day and storm-day failures. The locations of sixteen cross sections are shown on Plate 2. These sixteen were selected to characterize the movement and attenuation of the dam-breach flood wave as it progresses downstream.

The geometry input to define the downstream channel does not include detailed bridge information. This study does not attempt to determine if any downstream structures will or will not fail during a dam-breach at the Sunapee Lake Dam and subsequent failure of Town Dam. The dams at MM 11.90 and MM 16.17 were modeled as remaining intact as the increased stages at these dams due to the failure of the upstream dams was not significant. The calculated dam breach flood wave elevations at dams at MM 11.90 and MM 16.17 were less than the 100-Year flood levels at these structures.

5. RESULTS OF ANALYSIS

a. General. This section discusses results of the simultaneous dam failure analysis of the Sunapee Lake Dam and subsequent failure at the downstream Town Dam for the sunny-day and storm-day failures.

b. Breach Discharge Hydrograph. The peak breach discharges from the Sunapee Lake Dam and the Town Dam for the sunny-day and storm-day dam failures are listed below:

Dam	Peak Breach Discharges (CFS)	
	Sunny-day Failure	Storm-day Failure
Sunapee Lake Dam	500	1060
Town Dam	1370	2120

Tables 4 and 5 summarize the dam peak discharges and the downstream channel routing results under a sunny-day and storm-day failure, respectively.

Plates 3 to 8 show the pre-breach and dam-breach flood profile for the sunny-day dam failure. Plates 9 to 14 show the pre-breach and dam-breach flood profile for the storm-day dam failure. Plates 15 and 17 shows the breach discharge and flow depth hydrographs for selected cross sections throughout the reach. Plates 16 and 18 shows how the breach flood peak discharge varies with distance downstream.

TABLE 4

Sunapee Lake Dams Failure
Downstream Channel Routing Results

Sunny-day Failure

Downstream Location (River Miles)	Peak Discharge (CFS)[1]	Peak Elevation (ft NGVD)	Time to Peak Elevation (hours)[2]	Pre-breach Flow Elevation (ft NGVD)	Increase in Depth of Flow (feet)
Sunapee Lake Dam (10.00)	500	1093.2	0.2	1093.2	0.0
Town Dam (10.12)	1370	1092.9	0.2	1091.0	1.9
St. Rt.11 (10.34)	910	1015.3	0.3	1009.5	5.8
North Road (10.93)	660	994.2	0.6	991.4	2.8
Dam at Wendell Marsh (11.90)	510	982.2	6.1[3]	979.8	2.4
St. Rt. 11 (12.75)	510	954.7	6.2	953.0	1.7
St. Rt. 11 (13.16)	510	912.5	6.3	909.7	2.8
Town of Newport (15.22)	510	845.7	6.8	844.2	1.5
Old Wooden Bridge (15.89)	510	839.9	7.2	838.8	1.1
Sugar River I Hydro Dam (16.17)	510	839.9	7.2	838.8	1.1

[1] Includes pre-breach flows and inflow from downstream watersheds
[2] Time to peak measured from start of breach at Sunapee Lake Dam
[3] The long travel times between MM 10.93 and MM 11.90 can be attributed to the hydraulic conveyance characteristics of the Sugar River valley at this location. MM 11.90 is located at the outlet of a significant marsh area. Analysis of the dam break hydrograph at this location shows that the river reaches elevation 981.9 at hour 2.0, and the maximum elevation of 982.2 occurs at hour 6.2. This shows that the marsh takes considerable time to reach its maximum level, however levels approaching maximum occur within a short period of time (i.e. 2 hours).

TABLE 5

Sunapee Lake Dams Failure
Downstream Channel Routing Results

Storm-day Failure

Downstream Location (River Miles)	Peak Discharge (CFS)[1]	Peak Elevation (ft NGVD)	Time to Peak Elevation (hours)[2]	Pre-breach Flow Elevation (ft NGVD)	Increase in Depth of Flow (feet)
Sunapee Lake Dam (10.00)	1060	1095.9	0.2	1095.9	0.0
Town Dam (10.12)	2120	1095.4	0.2	1095.0	0.4
St. Rt.11 (10.34)	1840	1017.4	0.3	1015.9	1.5
North Road (10.93)	1470	996.3	0.5	994.8	1.5
Dam at Wendell Marsh (11.90)	1060	984.1	3.2[3]	983.5	0.6
St. Rt. 11 (12.75)	1060	956.0	3.8	955.6	0.4
St. Rt. 11 (13.16)	1060	914.3	3.8	913.8	0.5
Town of Newport (15.22)	1060	846.4	3.9	846.2	0.2
Old Wooden Bridge (15.89)	1060	840.9	4.6	840.6	0.3
Sugar River I Hydro Dam (16.17)	1060	840.8	4.6	840.5	0.3

[1]Includes pre-breach flows and inflow from downstream watersheds
[2] Time to peak measured from start of breach at Sunapee Lake Dam
[3] See discussion of long travel times between MM 10.93 and MM 11.90 in foot note 3 for table 4. At MM 11.90 the river will reach an elevation of 983.99 at hour 1.3, and due to the hydraulic characteristics of this reach the maximum peak elevation of 984.1 occurs at hour 3.2.

6. DOWNSTREAM CHANNEL ROUTING

Plates 3 to 8 and Plates 9 to 14 show peak water surface profiles resulting from the pre-breach initial flow and failure flow of both the sunny-day and storm-day failure conditions, respectively. The peak dam-breach discharge computed by the DAMBRK computer program for the sunny-day failure is 1370 cfs and 2120 cfs for the storm-day failure.

The analysis was conducted in one reach from Sunapee Lake Dam at MM 10.00 to Sugar River I Hydro Dam on the Sugar River in the Town of Newport, New Hampshire at MM 16.17 a distance of 6.17 miles. As mentioned previously, this analysis includes a dam failure simulation of the Sunapee Lake Dam with a subsequent dam failure of the Town Dam which is approximately 750 feet downstream of the Sunapee Lake Dam. Both dams were assumed to fail in 0.2 hours.

Since the maximum breach width at Sunapee Lake Dam, MM 10.00, is only 21 feet, this narrow cross section **controls** the peak discharge that can be released from the dam failure breach opening and produces a slow drawdown of the Sunapee Lake water storage.

The dams located downstream of Sunapee Lake Dam and Town Dam are the dams at Wendell Marsh (MM 11.90) and the dam at MM 16.17. The intent of this study is not to determine if, or when, these dams would fail. The adopted dam-breach conditions assume that these dams remain.

The increase in the dam-breach flood over the assumed pre-breach flood levels is an indication of the flooding that can be expected as a result of a dam-breach. It is again noted, that the assumed pre-breach flood conditions are rare conditions for the storm-day event, and there would be flooding prior to failure. These pre-breach high flows are due to uncontrolled spillway discharges at the dam, and not attributable to a dam failure.

7. INUNDATION MAPPING

The limits of inundation were computed by routing the breach discharge hydrograph through the downstream valley cross sections and delineating the resulting maximum stages on the base map. Mapping will be done by the Department of Environmental Services, and will be included in the Emergency Action Plan prepared by them. The base map used is based on a 20-foot contour interval 1:24,000 scale USGS quadrangle. Locations of the sixteen selected downstream stations are graphically illustrated on Plate 2. Although any structures shown within these limits were assumed to be inundated, certain structures may be excluded as a result of local conditions and elevations.

8. DISCUSSION

The dam-breach analysis for Sunapee Lake Dam and the Town Dam was based on engineering application of certain laws of physics, considering the physical characteristics of the project and downstream channel and conditions of failure. Due to the highly unpredictable nature of a dam-breach and the ensuing sequence of events, the results of this study should not be

viewed as exact but only as an approximate quantification of the dam-breach flood potential. For purposes of analysis, downstream conditions are assumed to remain constant, and no allowance is made for possible enlargement or relocation of the river channel due to scour or temporary damming effects, all of which could affect, to some extent, the resulting magnitude and timing of flooding.

The results of a dam failure could be damaging at areas downstream of the dam. However, for the adopted storm-day pre-breach flows, due to uncontrolled spillway discharges associated with these rare events, channel capacities would have been exceeded and flooding would have occurred prior to a dam-breach at the dam. It should be noted that a dam failure occurring during a more frequent (less severe) event would result in a more prominent rise over pre-breach flood levels.

Also, this study does not attempt to determine if any downstream structures will or will not fail during a dam-breach at the Sunapee Lake Dam and the Town Dam. For this study, the downstream dam structures were modeled as remaining intact. This approach was viewed as the most conservative one, resulting in higher peak water surface elevations behind them than if the dams were breached.

The dam-breach analysis ended on the Sugar River, about six miles downstream of Sunapee Lake Dam. The State of New Hampshire's criteria for ending dam-breach analyses is to compute the water surface elevation downstream of the dam until the breach water surface elevations are within 2.0 feet of the pre-breach water surface elevations. Sunapee Lake Dam and the Town Dam, dam failure flows are within 2.0 feet of pre-breach flow levels on the Sugar River at an existing dam (MM 16.17) located approximately 4,000 feet upstream of the confluence of the Sugar River and the South Branch of the Sugar River.

9. REFERENCES

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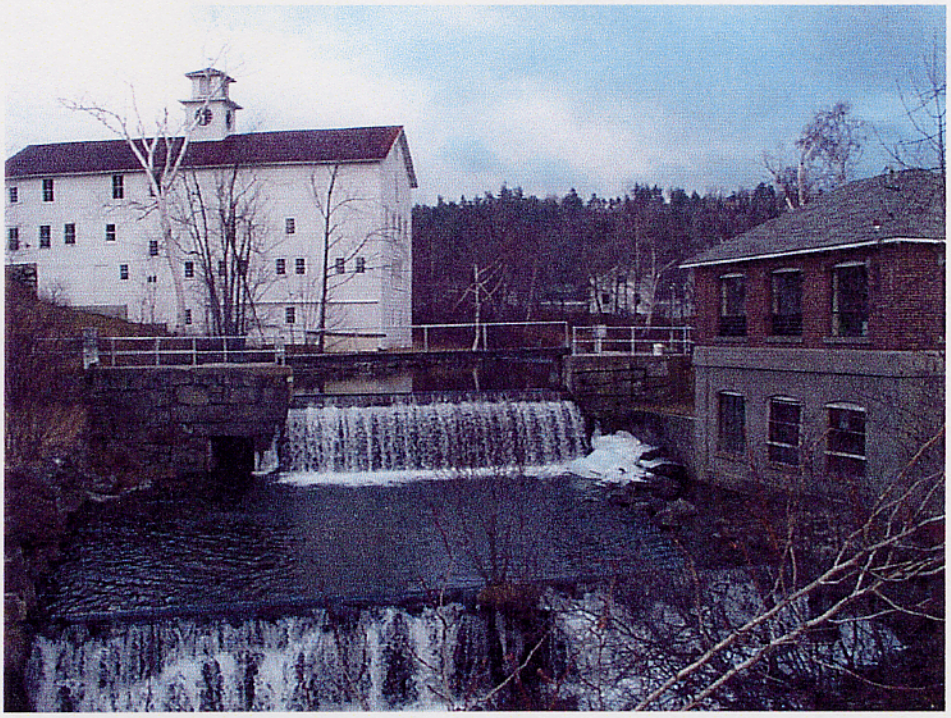
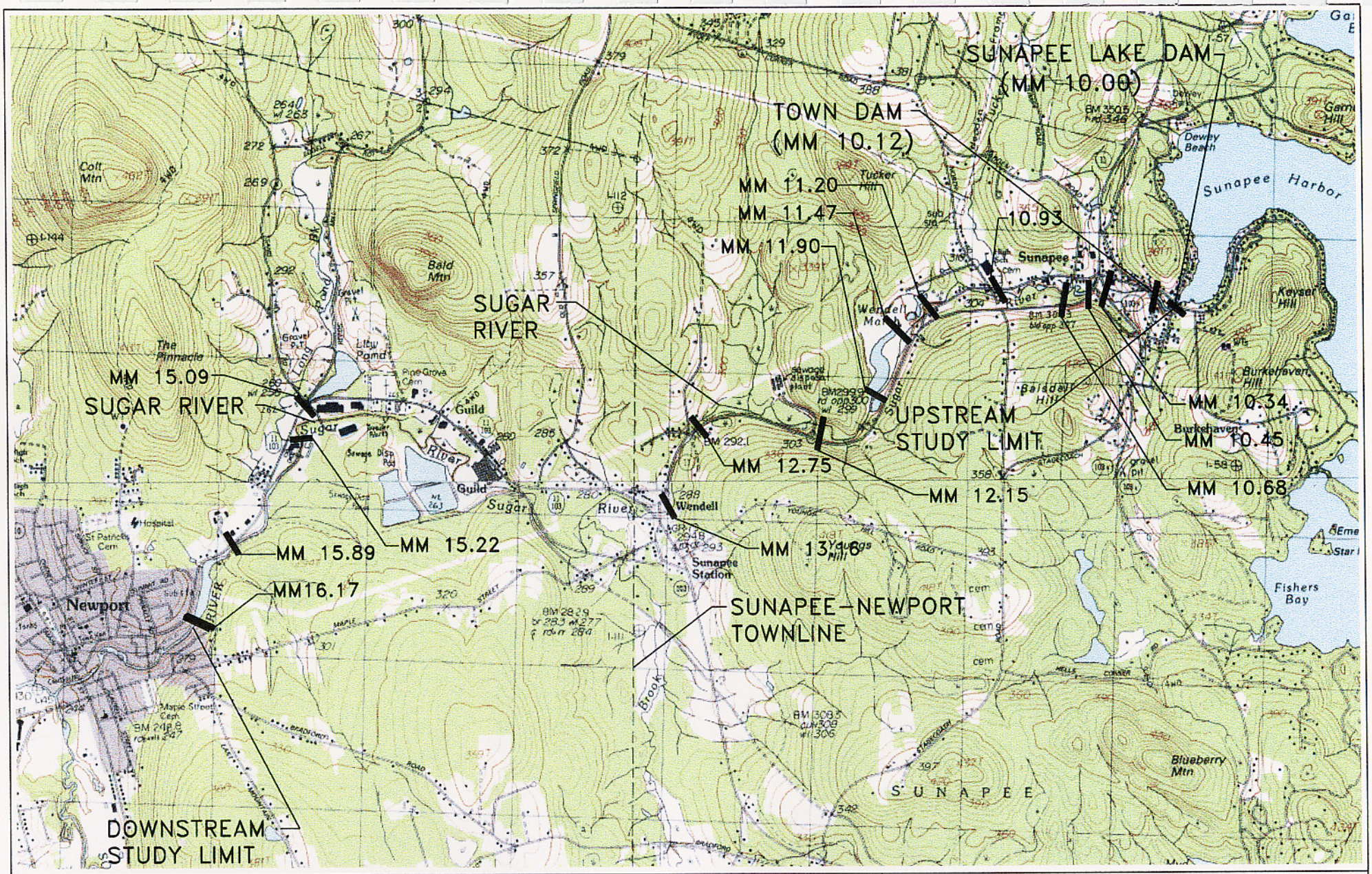
PLATES

Sunapee Lake Dam looking southwest. (Looking downstream)



Town Dam looking upstream

PLATE 1



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MAP FROM U.S.G.S.
NEWPORT, N.H. QUADRANGLE
SUNAPEE, N.H. QUADRANGLE
BOTH CREATED 1984

1" = 2900'±
SCALE IN FEET

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
CONCORD, MASSACHUSETTS

DuBois & King inc.
engineering planning management development

SUNAPEE LAKE DAM AND TOWN DAM
TOWN OF SUNAPEE, NEW HAMPSHIRE

DAM-BREAK FLOOD ANALYSIS

PLATE 2
CROSS-SECTION LOCATION AND SITE MAP

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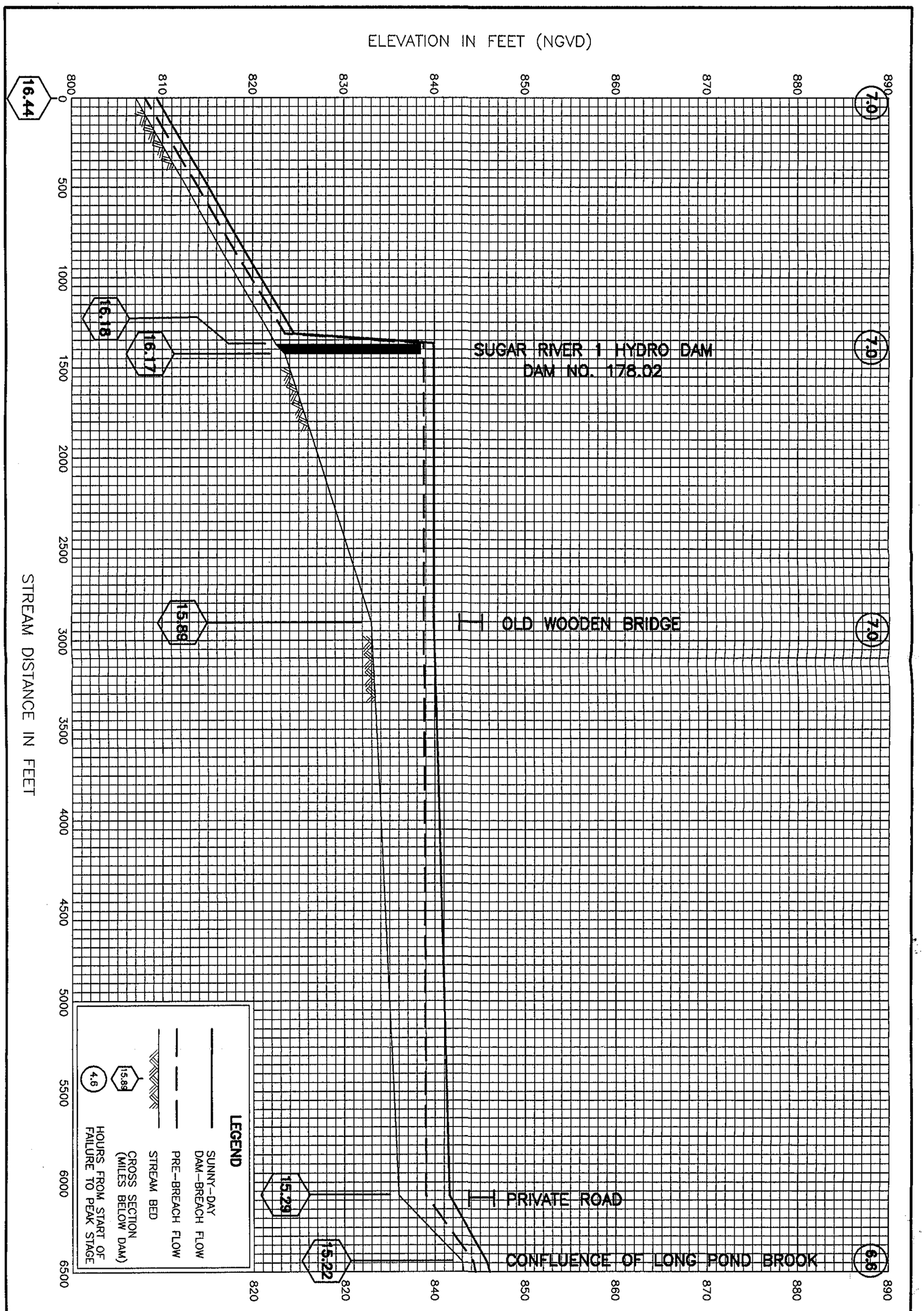
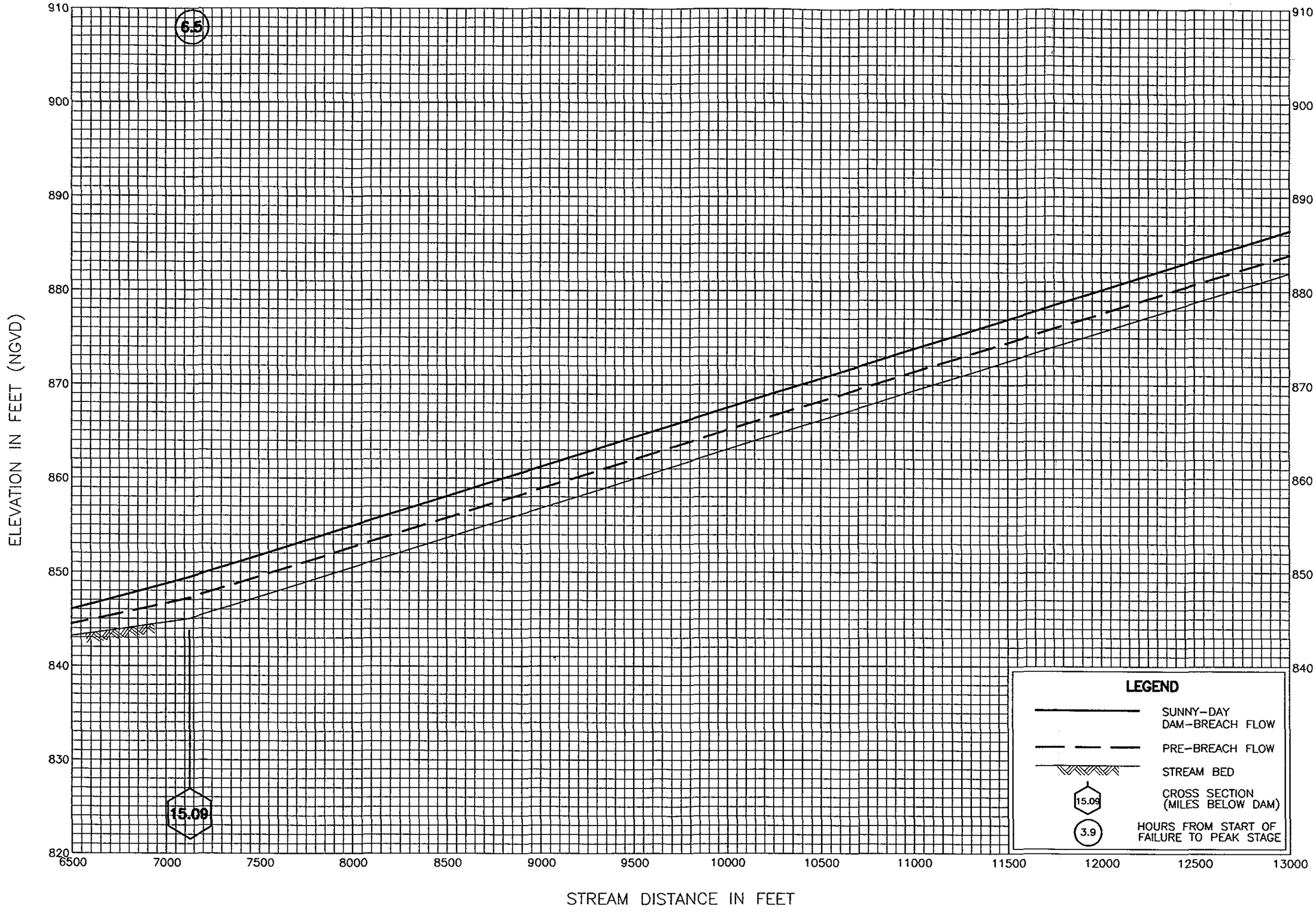


PLATE NO. 3	SUNAPEE LAKE DAM AND TOWN DAM SUNNY-DAY DAM-BREACH FLOOD ANALYSIS TOWN OF SUNAPEE, NH	FLOOD PROFILES SUGAR RIVER



FLOOD PROFILES

SUGAR RIVER

SUNAPEE LAKE DAM AND TOWN DAM
SUNNY-DAY
DAM-BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE
NO. 4

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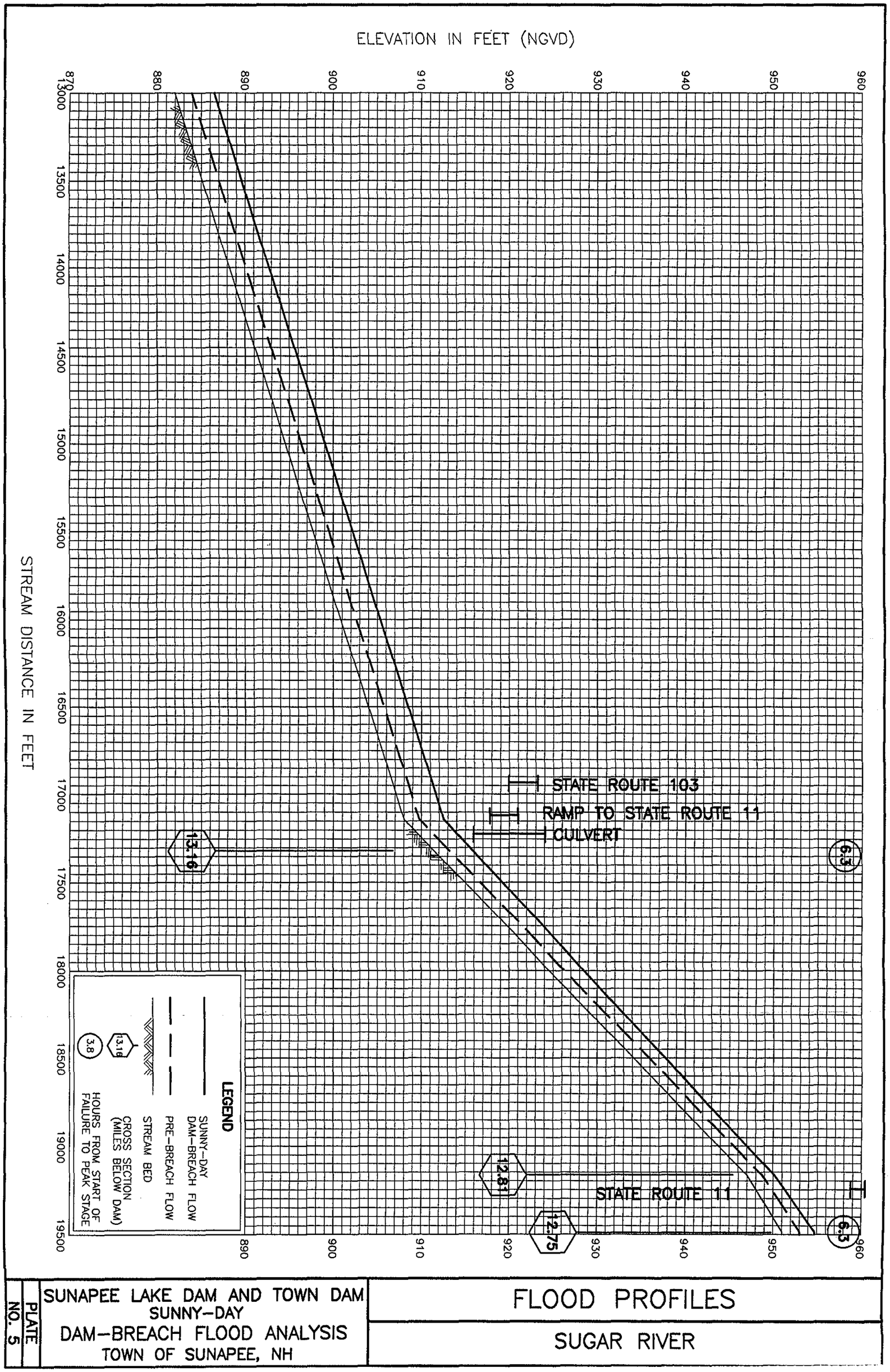
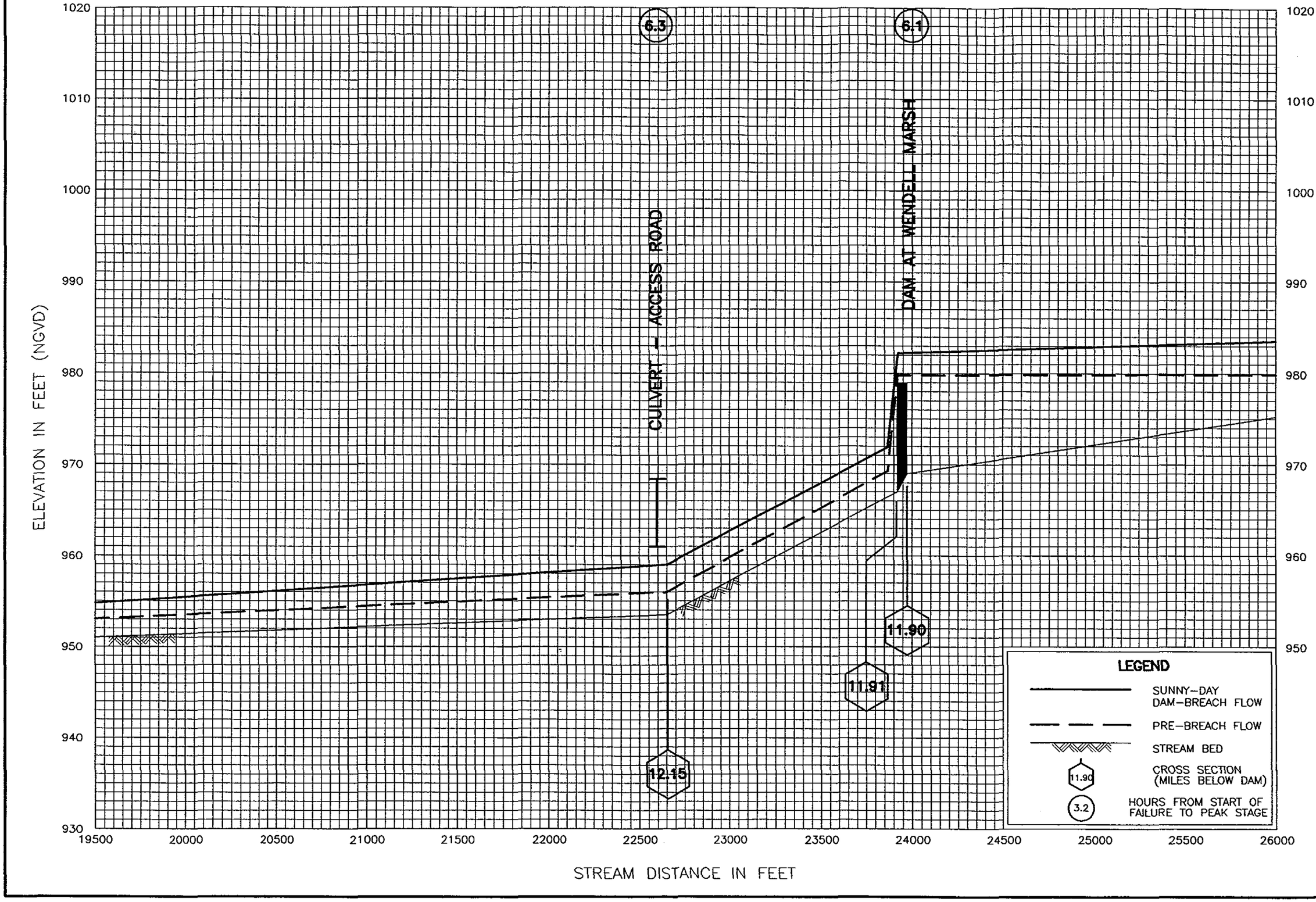


PLATE NO. 5	SUNAPEE LAKE DAM AND TOWN DAM SUNNY-DAY DAM-BREACH FLOOD ANALYSIS TOWN OF SUNAPEE, NH	FLOOD PROFILES SUGAR RIVER



FLOOD PROFILES

SUGAR RIVER

SUNAPEE LAKE DAM AND TOWN DAM
SUNNY-DAY
DAM-BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE
NO. 6

\\leonardo\data\PROJECTS\R15707L6\dwg\Profile\SUNAPEESUNNY.dwg Wed Apr 05 16:08:13 2000

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ELEVATION IN FEET (NGVD)

950 960 970 980 990 1000 1010 1020 1030 1040

STREAM DISTANCE IN FEET

26000 26500 27000 27500 28000 28500 29000 29500 30000 30500 31000 31500 32000 32500

11.47

11.20

10.93

10.68

5.6

0.6

0.6

0.5

PRIVATE DIRT ROAD

PRIVATE DIRT ROAD

LOWER MAIN STREET

NORTH ROAD

PRIVATE ROAD

LEGEND

- SUNNY-DAY
- DAM-BREACH FLOW
- PRE-BREACH FLOW
- STREAM BED
- 10.93 CROSS SECTION (MILES BELOW DAM)
- 0.5 HOURS FROM START OF FAILURE TO PEAK STAGE

970 980 990 1000 1010 1020 1030 1040

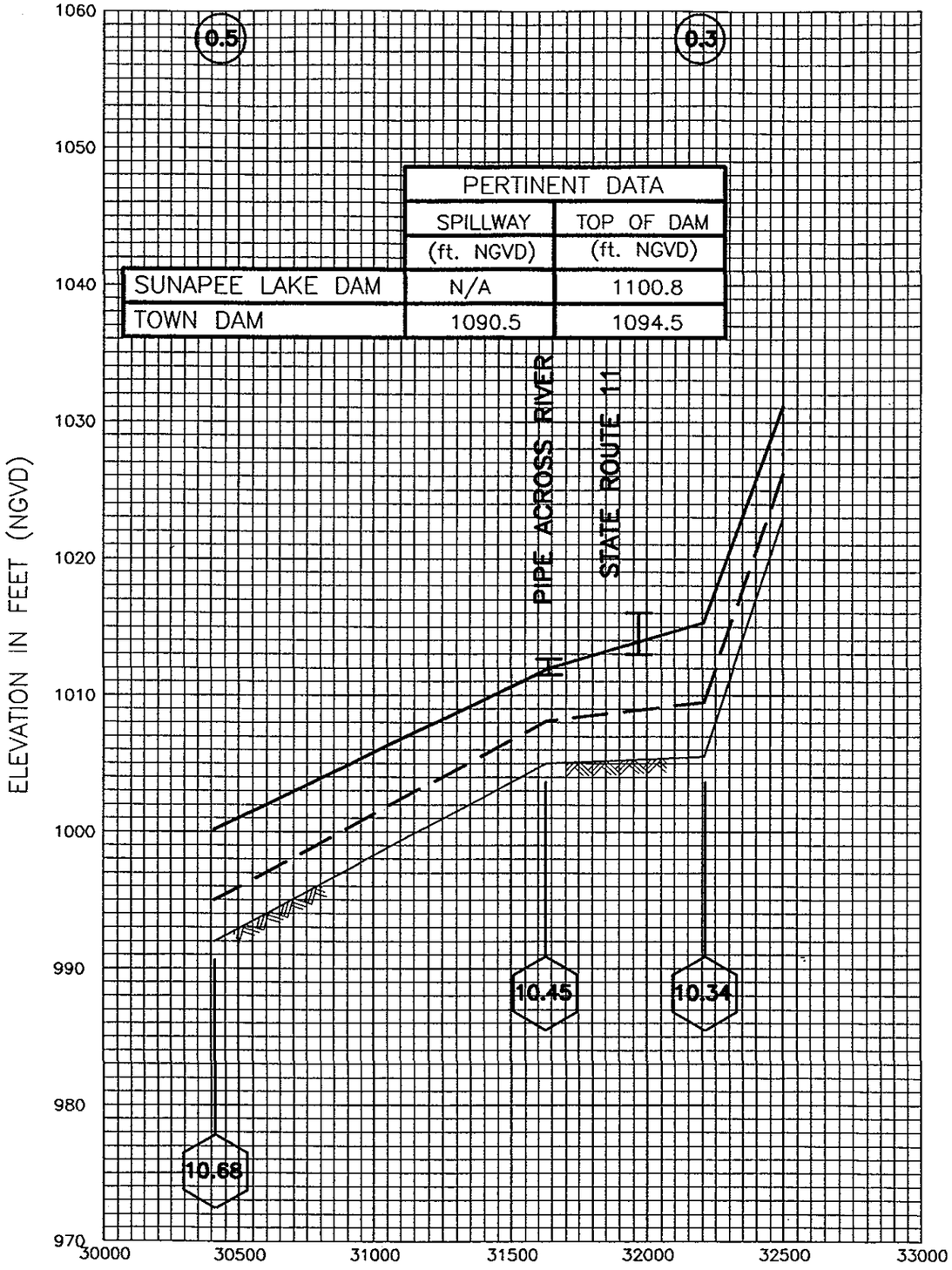
FLOOD PROFILES

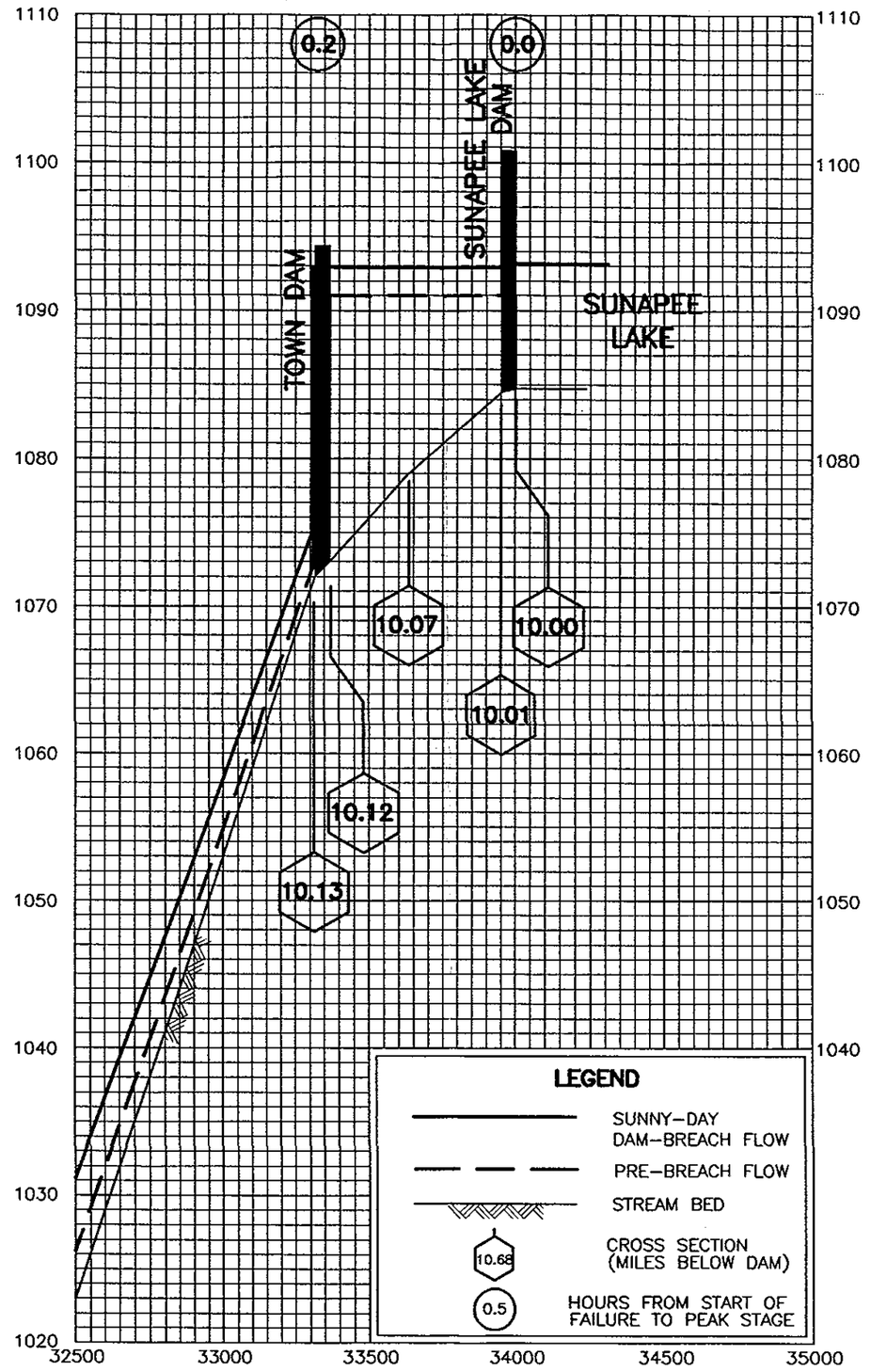
SUGAR RIVER

SUNAPEE LAKE DAM AND TOWN DAM
SUNNY-DAY
DAM-BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE NO. 7

PERTINENT DATA		
	SPILLWAY (ft. NGVD)	TOP OF DAM (ft. NGVD)
SUNAPEE LAKE DAM	N/A	1100.8
TOWN DAM	1090.5	1094.5





STREAM DISTANCE IN FEET

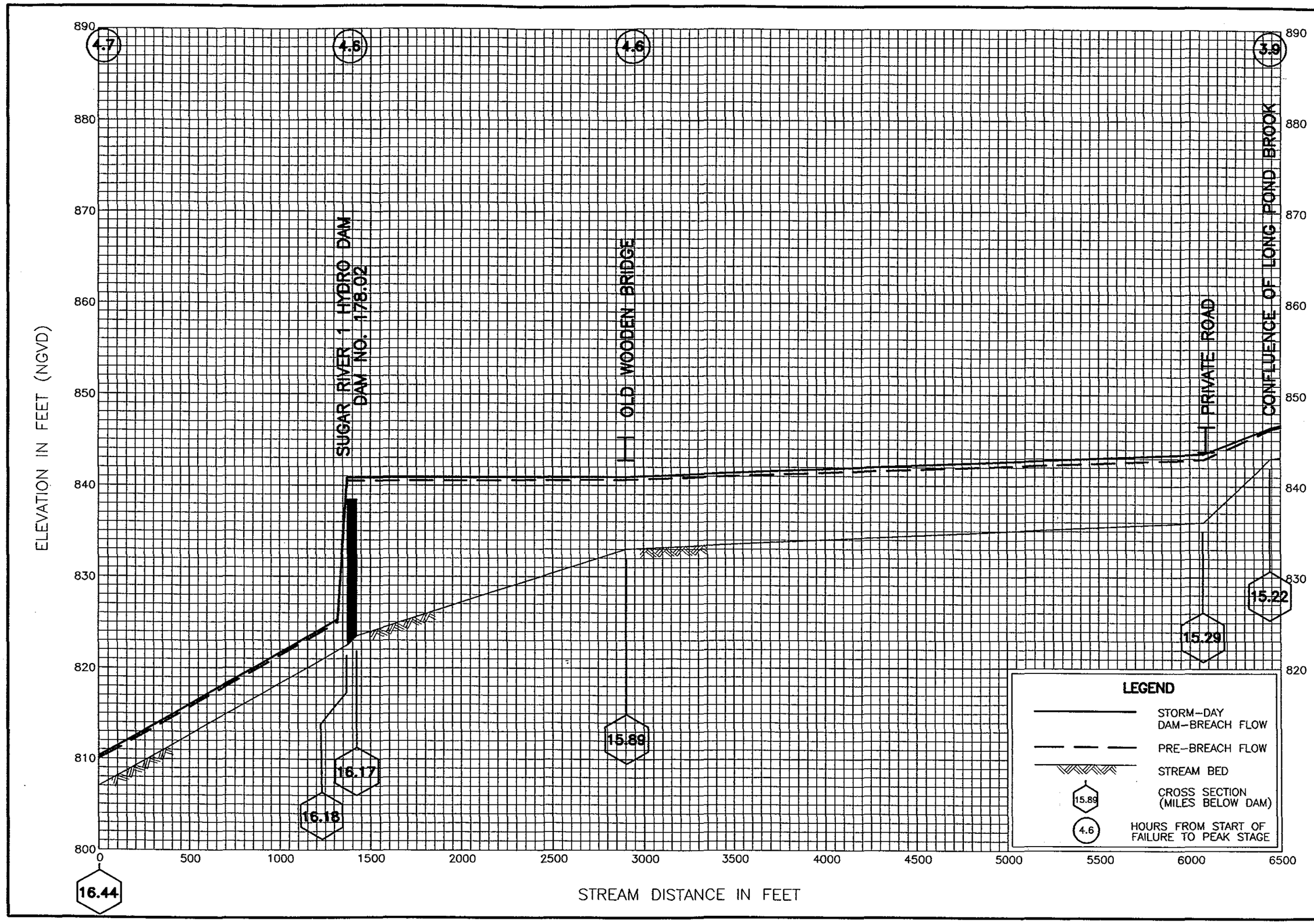
FLOOD PROFILES

SUGAR RIVER

SUNAPEE LAKE DAM AND TOWN DAM
SUNNY-DAY
DAM-BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE NO. 8

\\leonardo\data\PROJECTS\R15707L6\dwg\Profile\SUNAPEEstormUS.dwg Wed Apr 05 16:36:52 2000



FLOOD PROFILES

SUGAR RIVER

SUNAPEE LAKE DAM AND TOWN DAM
STORM-DAY
DAM-BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE NO. 9

\\leonardo\data\PROJECTS\R15707L6\dwg\Profile\SUNAPEEstormy.dwg Wed Apr 05 16:44:15 2000

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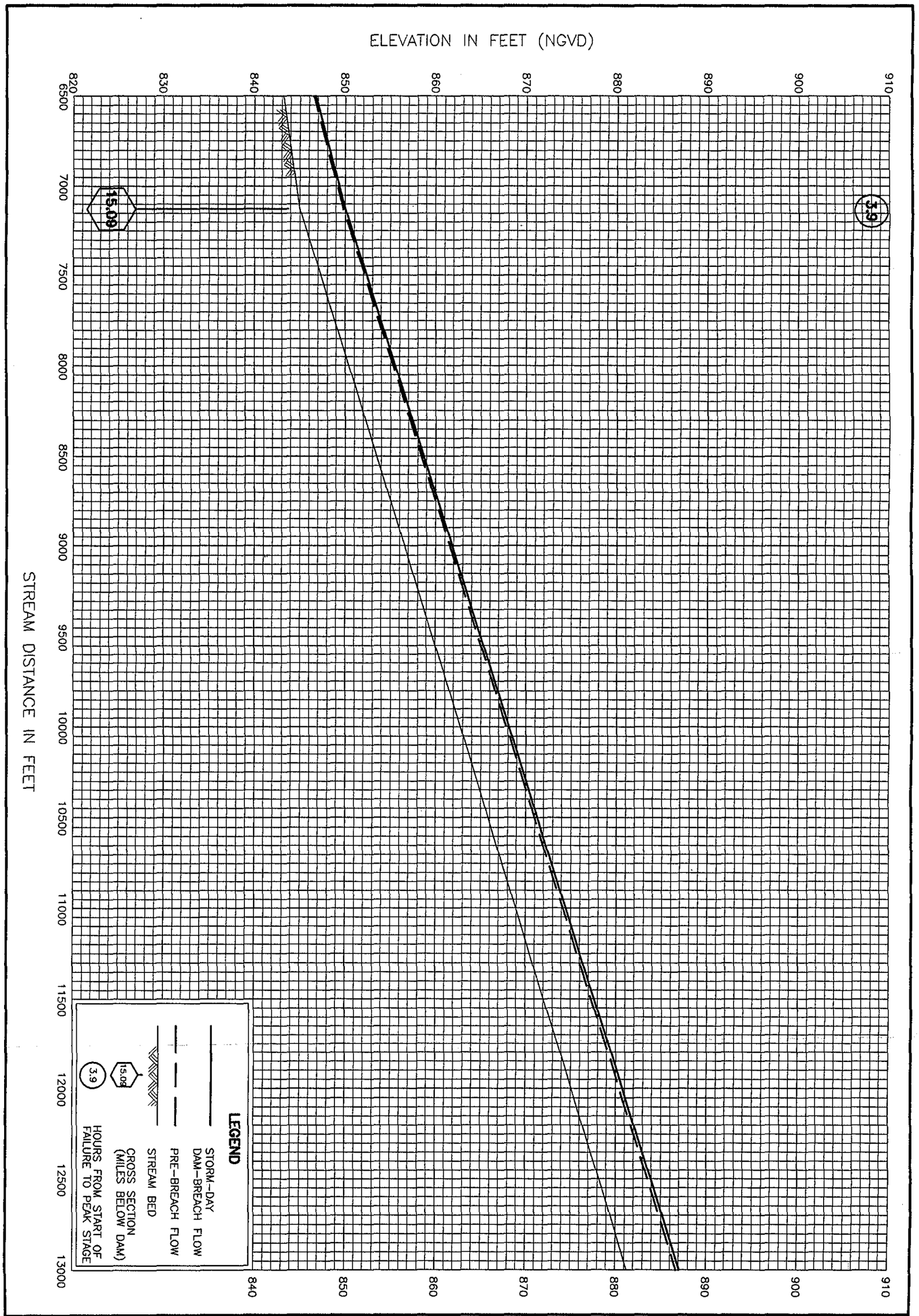

PLATE NO. 10

SUNAPEE LAKE DAM AND TOWN DAM
STORM-DAY
DAM-BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

FLOOD PROFILES

SUGAR RIVER

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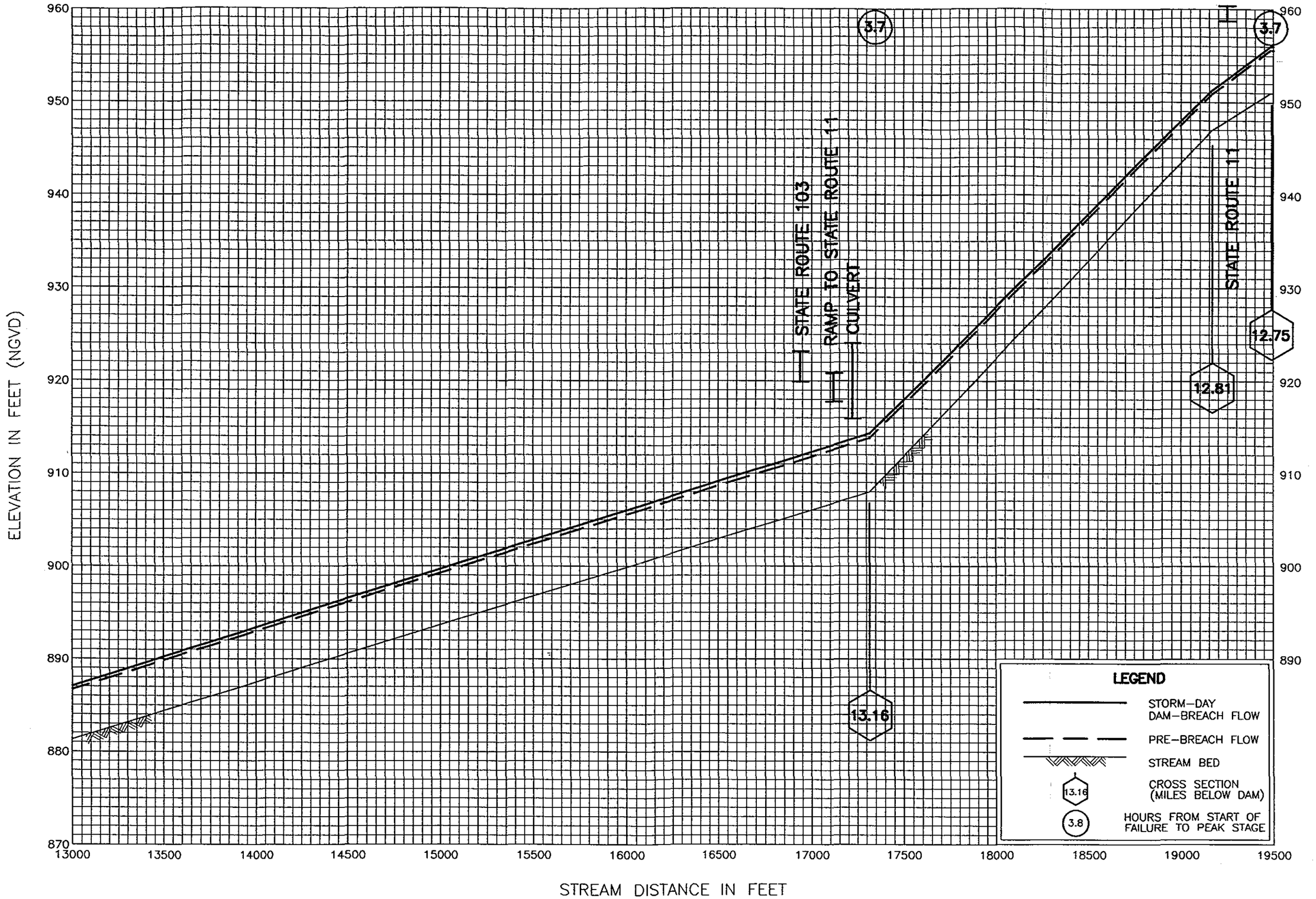
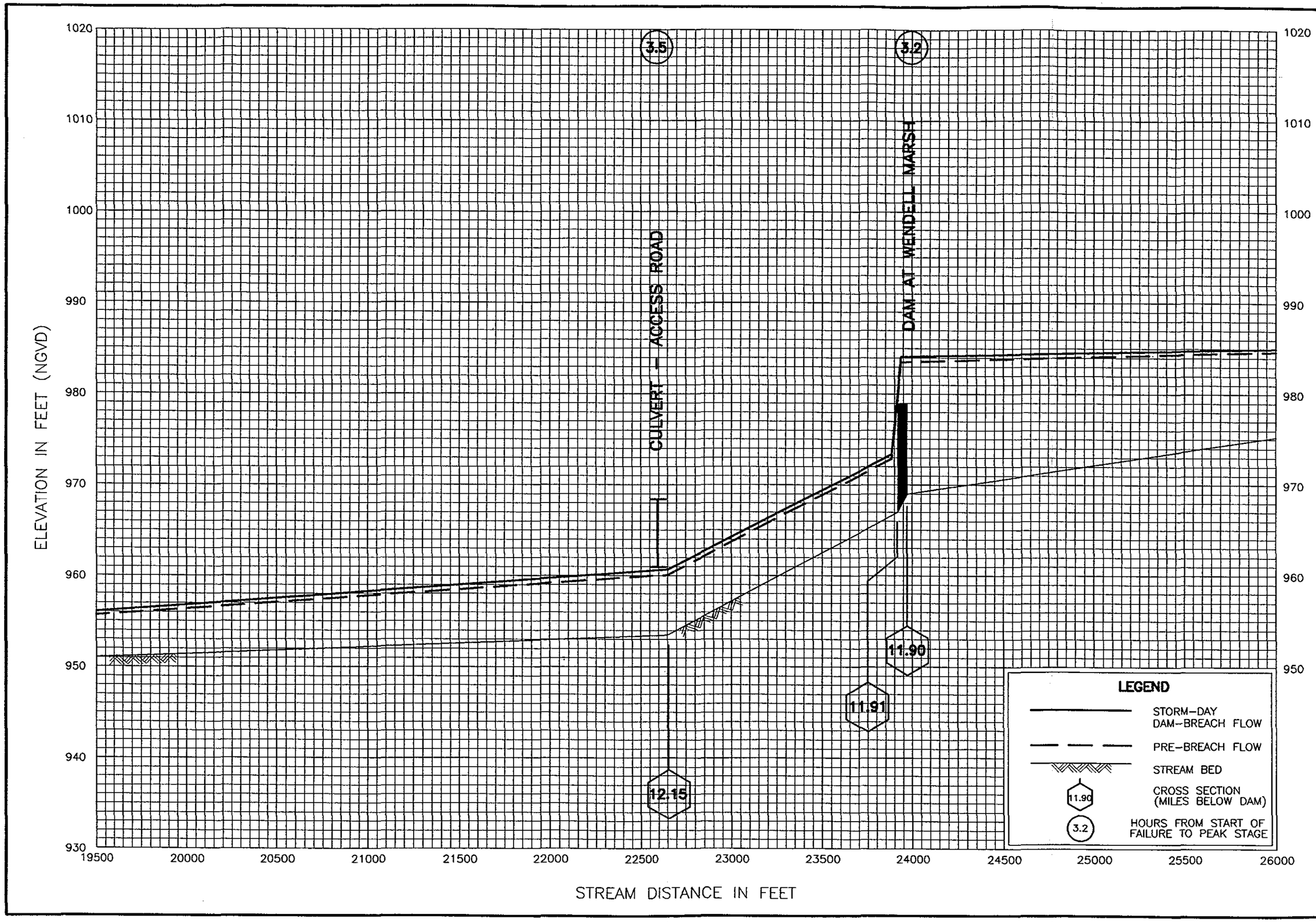


FLOOD PROFILES

SUGAR RIVER

SUNAPEE LAKE DAM AND TOWN DAM
STORM–DAY
DAM–BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE
NO. 11



FLOOD PROFILES

SUGAR RIVER

SUNAPEE LAKE DAM AND TOWN DAM
STORM-DAY
DAM-BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE NO. 12

\\leonardo\data\PROJECTS\R15707L6\dwg\Profile\SUNAPEEstormy.dwg Wed Apr 05 16:45:48 2000

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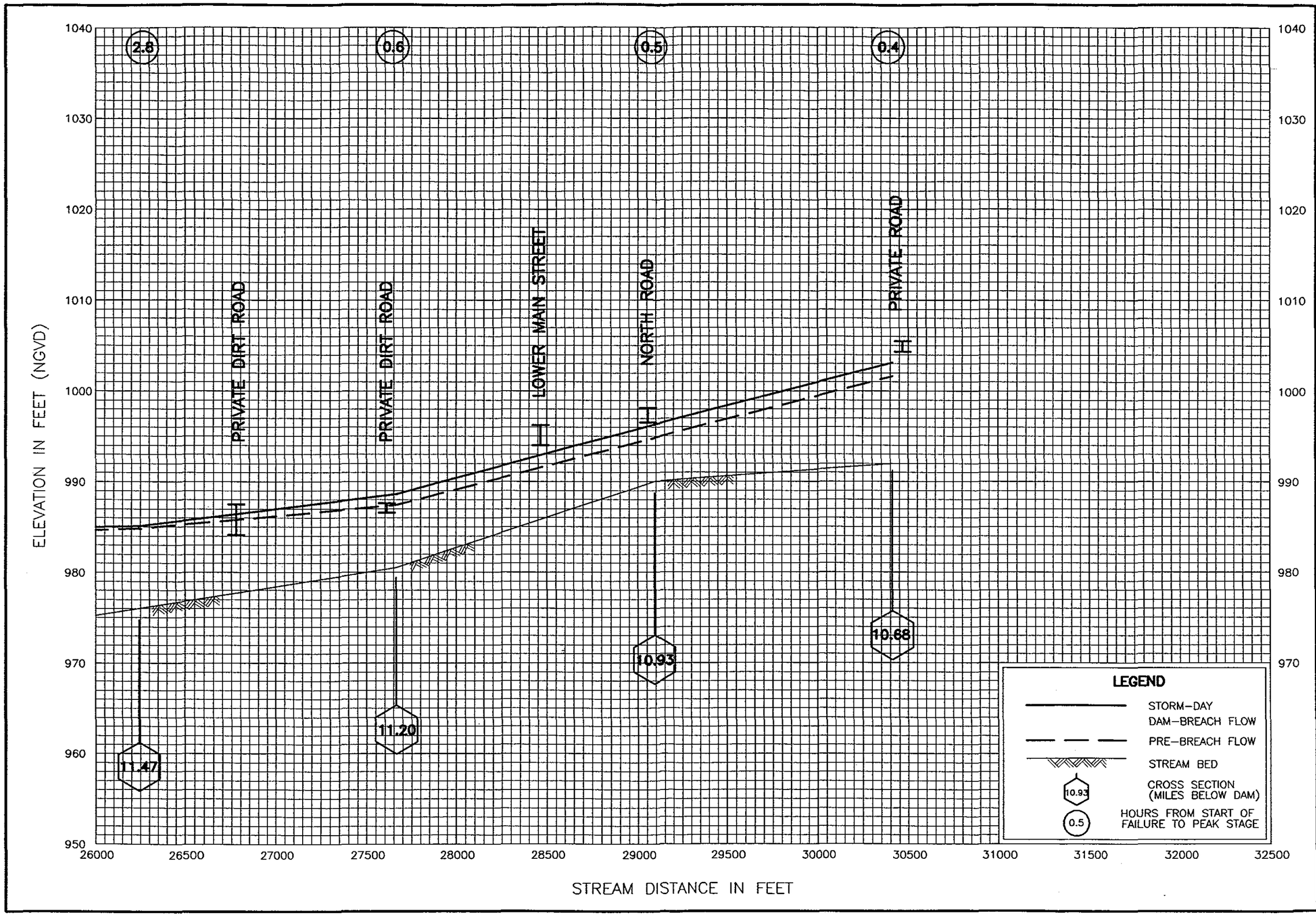


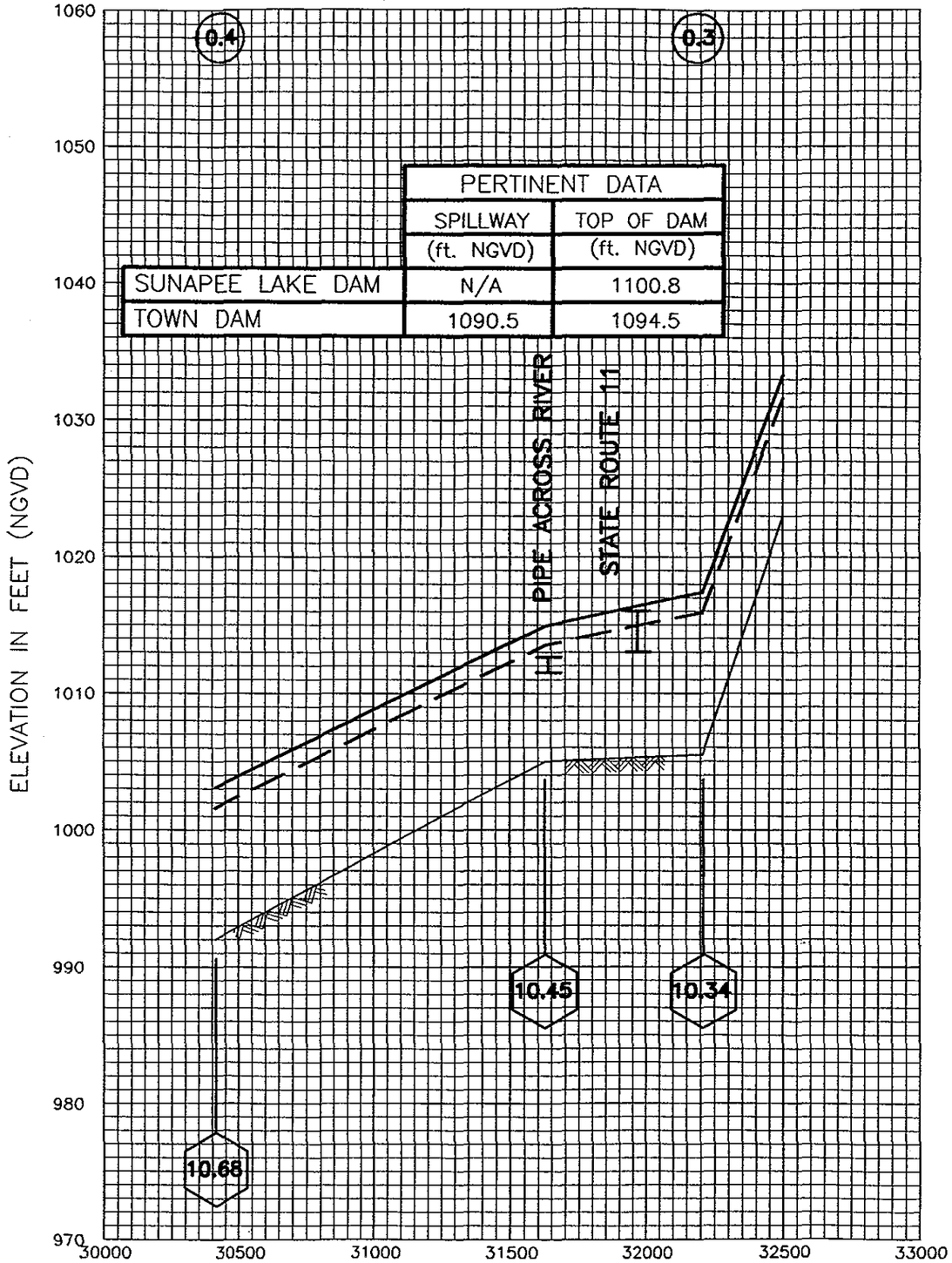
FLOOD PROFILES

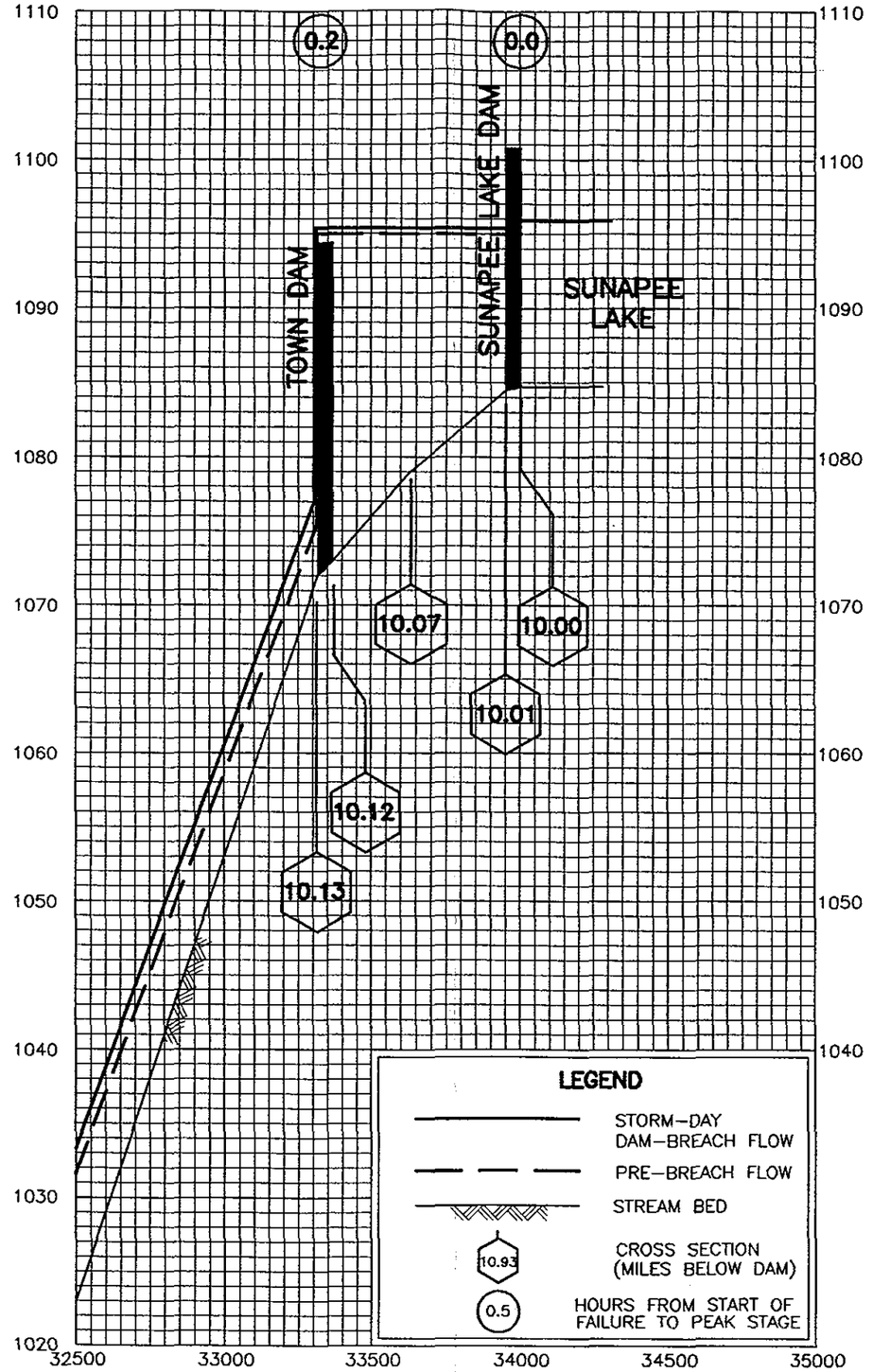
SUGAR RIVER

SUNAPEE LAKE DAM AND TOWN DAM
STORM-DAY
DAM-BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE NO. 13

PERTINENT DATA		
	SPILLWAY (ft. NGVD)	TOP OF DAM (ft. NGVD)
SUNAPEE LAKE DAM	N/A	1100.8
TOWN DAM	1090.5	1094.5





STREAM DISTANCE IN FEET

FLOOD PROFILES

SUGAR RIVER

SUNAPEE LAKE DAN AND TOWN DAM
STORM–DAY
DAM–BREACH FLOOD ANALYSIS
TOWN OF SUNAPEE, NH

PLATE NO. 14

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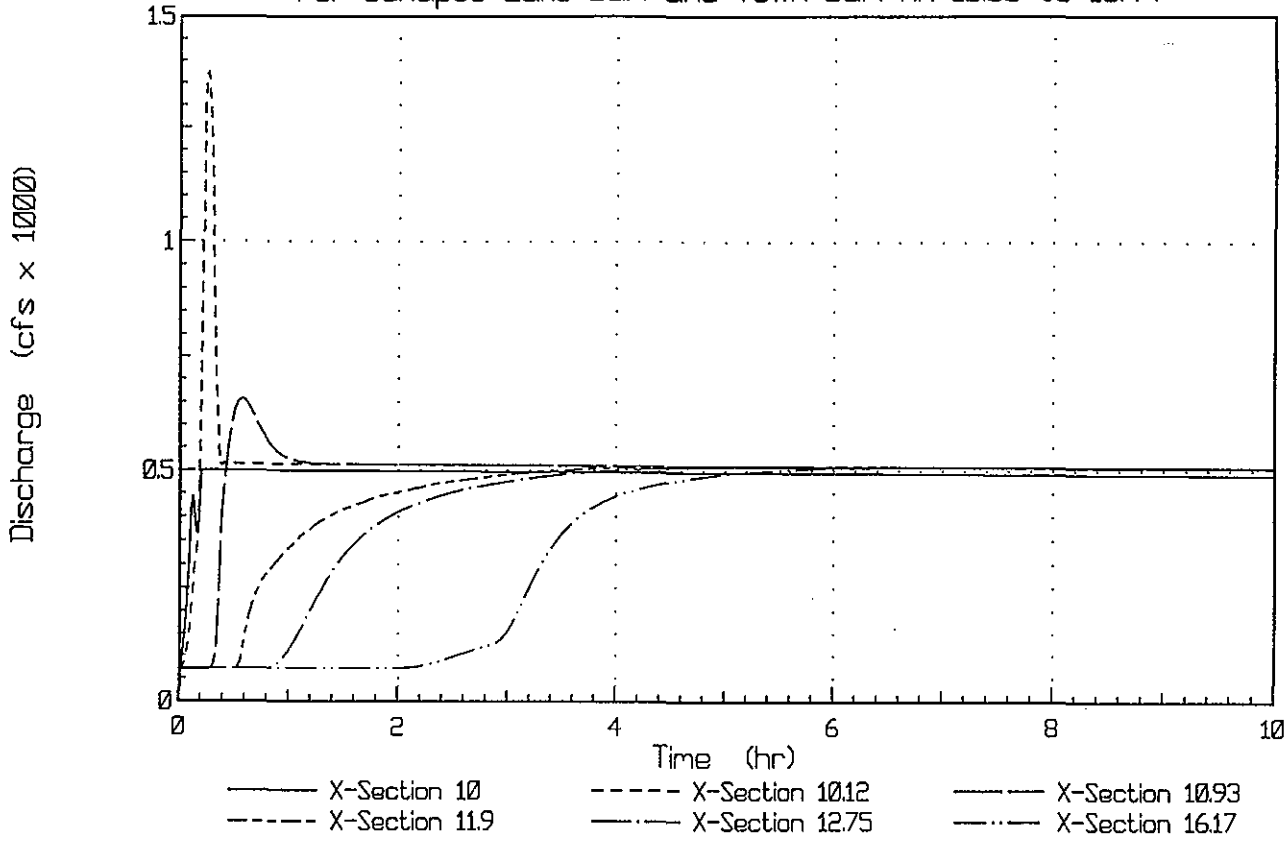
Combined Discharge Hydrographs - Sunny-day

For Sunapee Lake Dam and Town Dam MM 10.00 to 16.44



Combined Flow Depth Hydrographs - Sunny-day Failure

For Sunapee Lake Dam and Town Dam MM 10.00 to MM 16.44

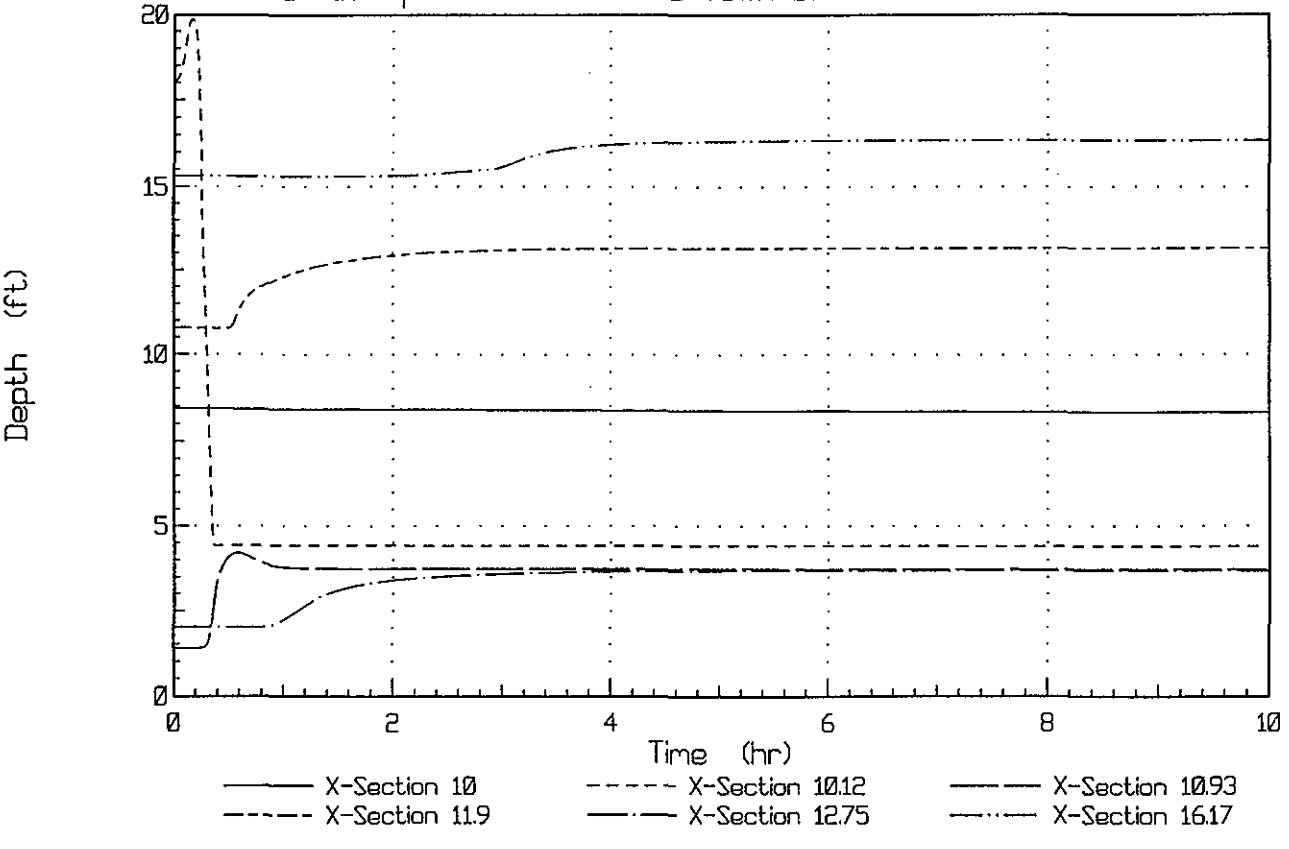
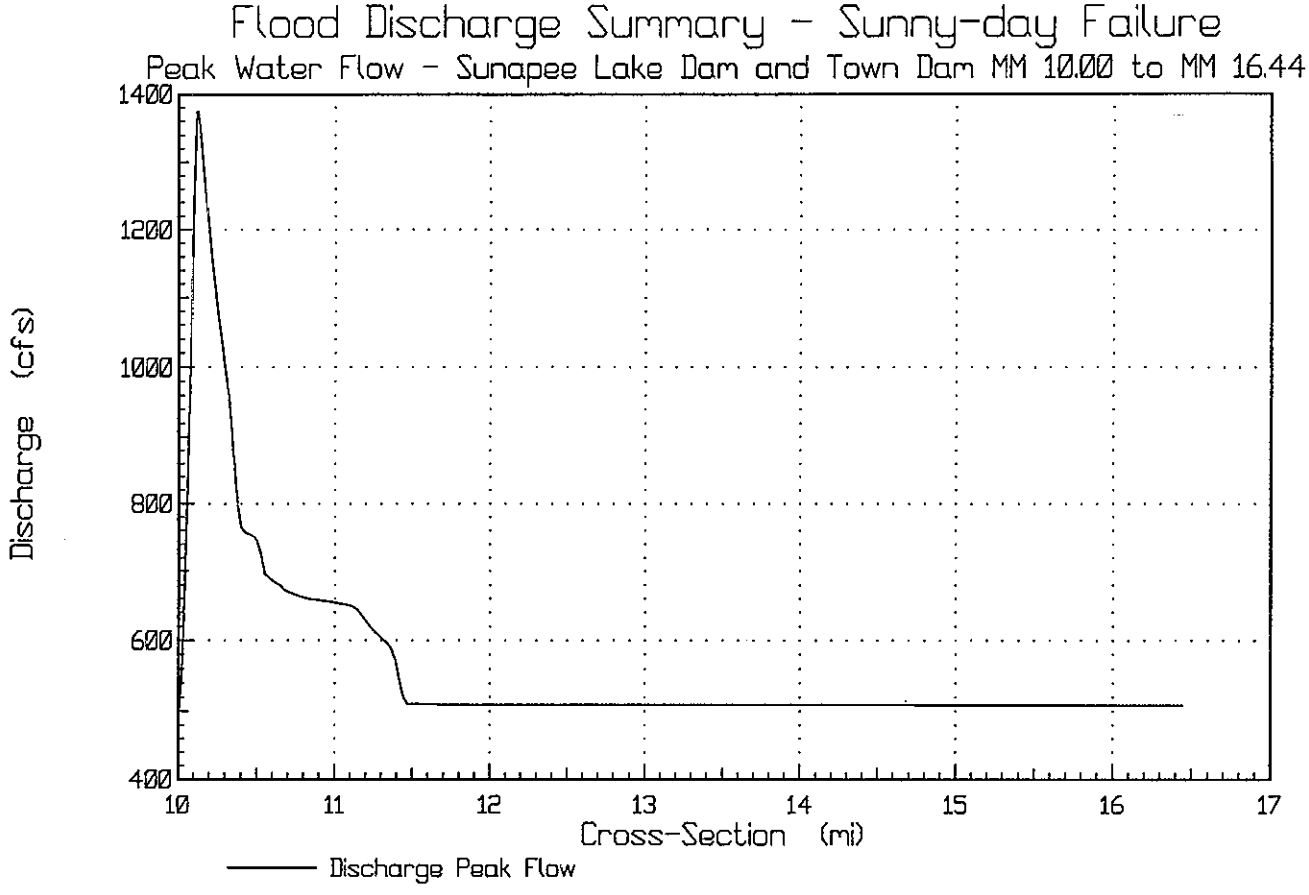
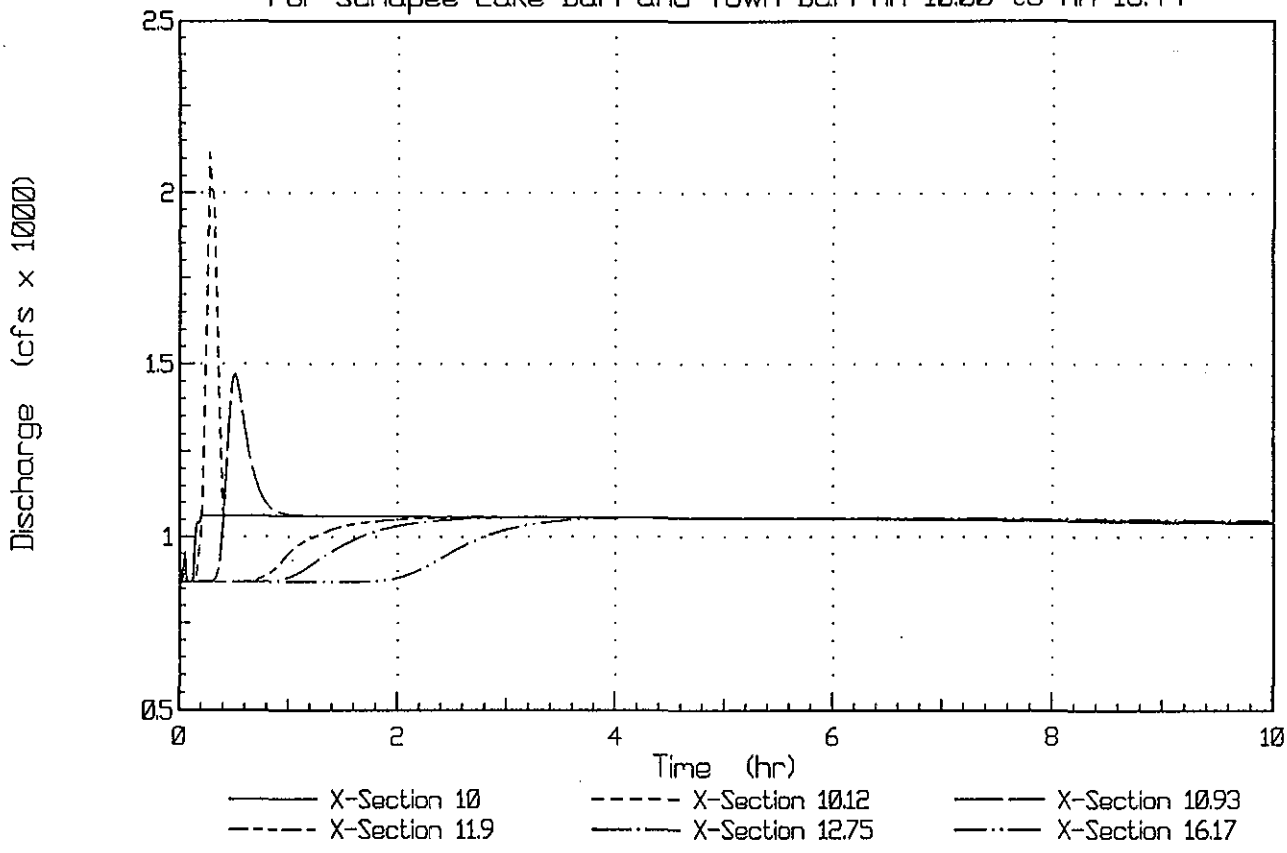


PLATE 15


Flood Discharge Summary - Sunny-day Failure
Peak Water Flow - Sunapee Lake Dam and Town Dam MM 10.00 to MM 16.44
Discharge (cfs)
1400
1200
1000
800
600
400
10
11
12
13
14
15
16
17
Cross-Section (mi)
Discharge Peak Flow

Combined Discharge Hydrographs - Storm-day Failure

For Sunapee Lake Dam and Town Dam MM 10.00 to MM 16.44



Combined Flow Depth Hydrographs - Storm-day Failure

For Sunapee Lake Dam and Town Dam MM 10.00 to MM 16.44

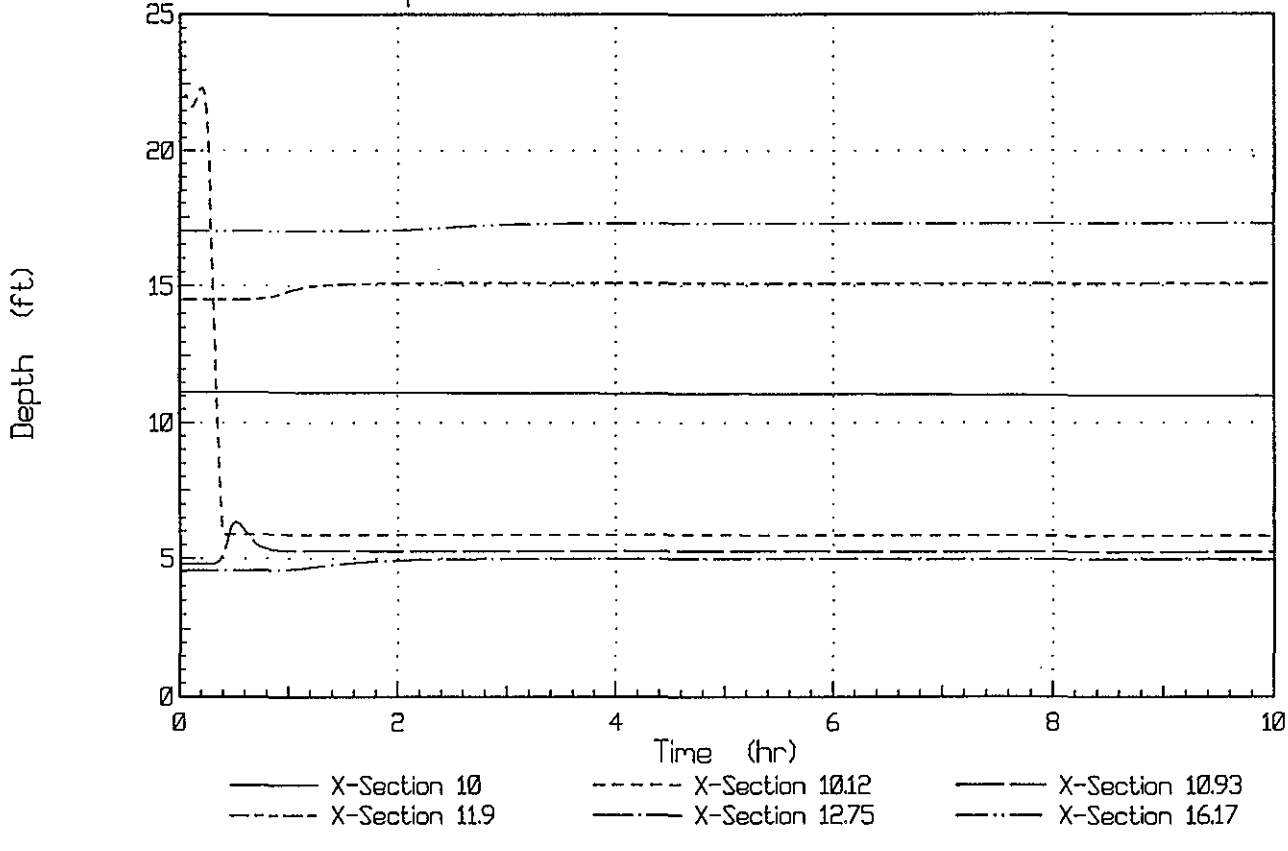
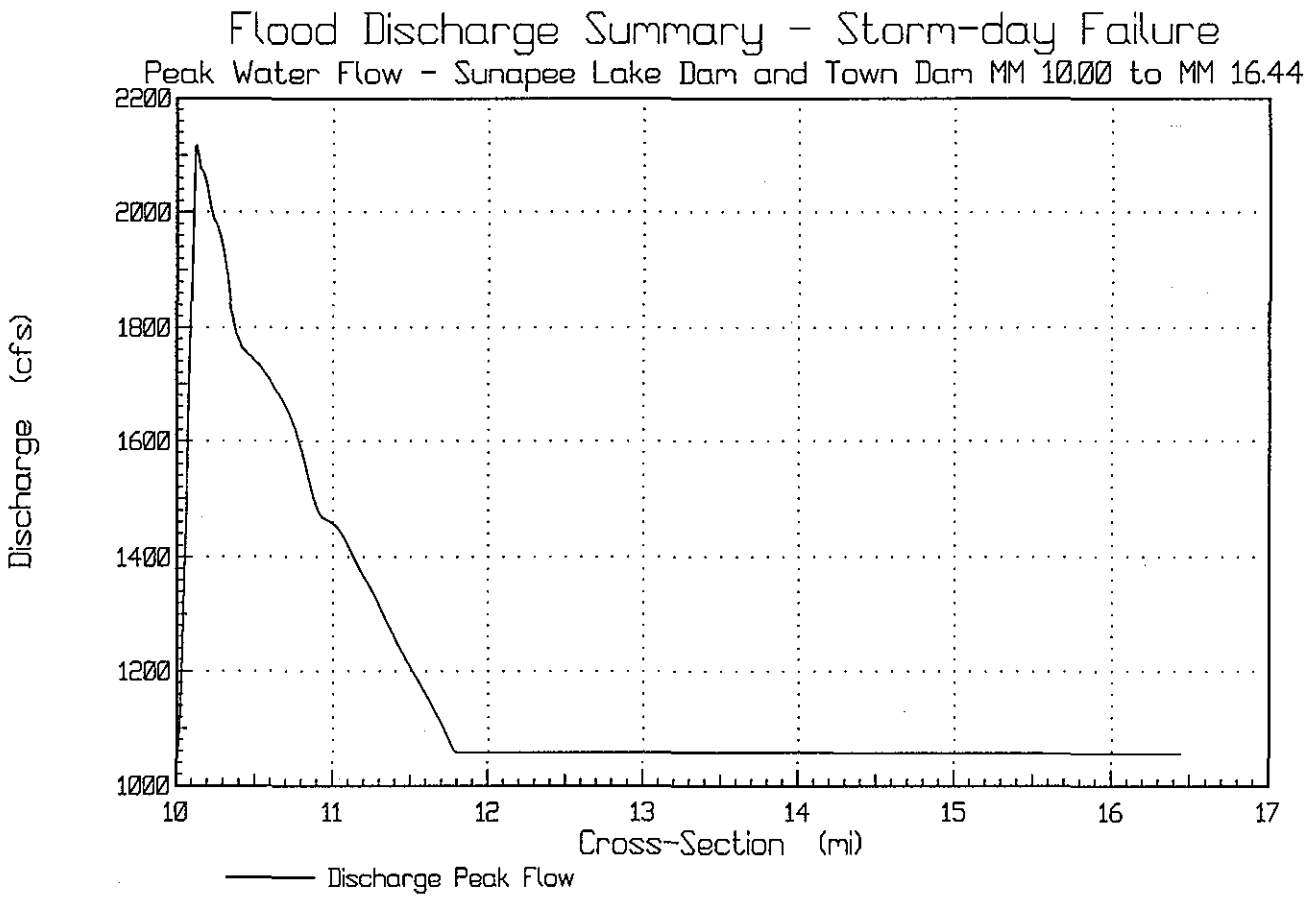


PLATE 17


Flood Discharge Summary - Storm-day Failure
Peak Water Flow - Sunapee Lake Dam and Town Dam MM 10.00 to MM 16.44
Discharge (cfs)
2200
2000
1800
1600
1400
1200
1000
10
11
12
13
14
15
16
17
Cross-Section (mi)
Discharge Peak Flow